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Diboson Physics Study with ATLAS

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The ATLAS prospects for the measurements of the WW, WZ and $W\gamma$ cross sections and the limits on the anomalous WWZ and $WW\gamma$ couplings at 14 TeV are summarized. The strategy to extract the signal and measure the triple gauge boson couplings is presented, focusing on early LHC data-taking. The results are obtained with full simulations of ATLAS detector, with included trigger selection, detector calibration and alignment corrections.

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Introduction. The local gauge symmetry of the Standard Model (SM) generates self interactions of the gauge fields which manifest themselves as a coupling of three or four gauge bosons such as WWZ, $WW\gamma$ or $WWZ\gamma$, $WW\gamma\gamma$. Within the SM the structure and the strength of these couplings are completely determined by the $SU(2)_L \times U(1)_Y$ symmetry and precise measurement of these couplings can either additionally confirm the SM or may indicate a new physics at an unprobed energy scale. The production of diboson pairs at the LHC provides a direct test of WWZ and $WW\gamma$ couplings at the highest possible energies.

In this report we summarize the most recent ATLAS results [1] on the strategy for study WW, WZ and $W\gamma$ production and the prospects for probing the WWZ and $WW\gamma$ triple gauge-boson couplings. These results are obtained with full simulation of the ATLAS detector, which include trigger selection, detector calibration and alignment corrections. For the analysis, the leptonic ($l = e$ or μ) decay modes of W and Z vector bosons are used. Signal and main background processes are modeled with MC@NLO+HERWIG (WW, WZ, ZZ, $t\bar{t}$), PYTHIA ($W\gamma$, Z) and ALPGEN+HERWIG ($W/Z+$ jets) generators.

WW production. At the LHC energies the W pairs are produced through both quark-antiquark annihilation, $q\bar{q} \rightarrow W^+W^-$ ($\sim$ 95%) and gluon-gluon fusion, $gg \rightarrow W^+W^-(\sim 5\%)$. The total NLO cross section for $q\bar{q} \rightarrow W^+W^-$ production is 111.6 pb, and 5.2 pb for the leptonic ($l = e$, μ) decay modes. The signature of the WW fully leptonic final state is two high p_T isolated leptons of opposite sign and large missing transverse energy ($\not{E}_T$). The events are triggered by a single isolated electron or muon with $p_T > 25$ GeV or $p_T > 20$ GeV. The trigger efficiency is $96-98\%$. Main background SM processes with similar signature are: $t\bar{t}$, Z/γ^*, $W^{\pm}Z$, ZZ, $W+$jets/γ where the jet/γ fakes an isolated electron or the jet contains a muon. Signal separation from the background (Fig.1) can be achieved with the following cuts: (1) two isolated leptons of opposite sign, with $p_T^l > 20$ GeV and $\mid \eta \mid < 2.5$; (2) no jets with $p_T^{jet} > 20$ GeV and $\mid \eta \mid < 3$; (3) $\not{E}_T > 50$ GeV; (4) $\mid M_Z - m(l^+l^-) \mid \ > 15$ GeV; (5) $\phi_{ll} < 2$ rad, or $\Phi(\mathbf{p}_T^{ll}, \not{\mathbf{p}}_T) > 175^0$. With 1 fb^{-1} of data, about 104 signal and 19 background events are expected. Multivariate Boosted Decision Trees (BDT) [2] technique can further improve signal efficiency. Using this technique, about 469 signal and about 92 background events are expected. The one-dimensional 95% C. L. limits on anomalous WWZ and $WW\gamma$ couplings [1] are: $-0.035 < \Delta\kappa_Z < 0.073$, $-0.040 < \lambda_Z < 0.038$, $-0.149 < \Delta g_Z^1 < 0.309$, $-0.088 < \Delta\kappa_\gamma < 0.089$, and $-0.074 < \lambda_\gamma < 0.165$, for form factor scale $\Lambda_{FF} = 2$ TeV, and for 10 fb^{-1} of data. The two-dimensional 95% C. L. limits with HISZ assumption [3], for various integrated luminosities are shown in Fig.1.

W$^{\pm}\gamma$ production. At the LHC, $W^{\pm}\gamma$ pairs are produced through $q\bar{q}'$ scattering. The total $W^{\pm}\gamma$ NLO cross section, for a photon E_T^γ above 7 GeV and a lepton-photon separation $\Delta R(l,\gamma) > 0.7$, is predicted to be 451.6 pb, dropping to 97.4 pb if W decays leptonically ($l = e$, μ). The signature of $W\gamma$ is one isolated high p_T lepton (e or μ), one isolated high E_T^γ photon, and large $\not{E}_T$ from the W neutrino. Three trigger types are investigated (isolated muon with $p_T > 20$ GeV, isolated electron with $p_T > 22$ GeV and photon with $E_T^\gamma > 50$ GeV) and trigger efficiency is $\approx 80\%$. The dominant background is inclusive W production with final state radiation (FSR), $W+$jets with jet mis-identified as photon and inclusive Z production with one electron mis-identified as photon. The BDT method is used to select the $W^{\pm}\gamma$ events. Three trainings are done to separate $l\gamma\nu$ events with FSR photons, signal photons from fake photons, and signal photons from the contamination of Z inclusive events. With 1 fb^{-1} of data, the expected number of $W^{\pm}\gamma$ and background events is 1604

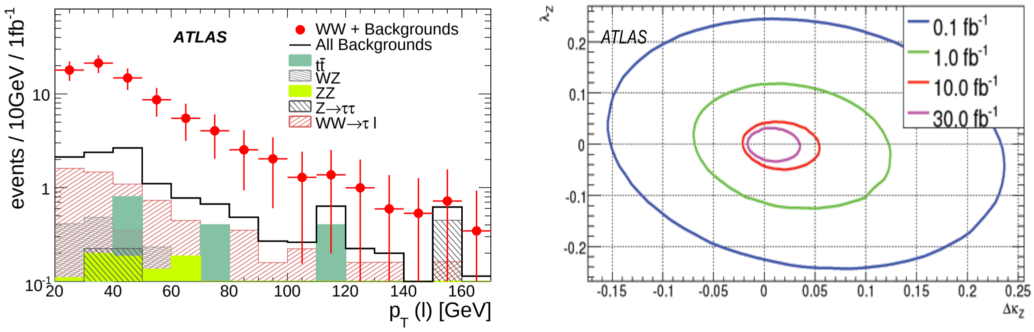

Figure 1: *Left*: p_T distribution of leptons, for WW events and $\int Ldt = 1$ fb^{-1}, after applying kinematic cuts; *Right*: 95% C. L. contour curves in the $\Delta\kappa_Z$, λ_Z plane, for various $\int Ldt$ and $\Lambda_{FF} = 2$ TeV.

and 1183 in $e\gamma\nu$ channel and 2166 and 1342 in $\mu\gamma\nu$ channel. The k factors used for the signal and background corrections to NLO cross sections are 1.66 and 1.3. The expected limits on anomalous $WW\gamma$ couplings at 95% C.L. are: $-0.26 < \Delta\kappa_\gamma < 0.07$, $-0.05 < \lambda_\gamma < 0.02$, for $\Lambda_{FF} = 2$ TeV, and for 10 fb^{-1} of data.

W$^{\pm}$Z production. The NLO cross section for $W^{\pm}Z$ production at 14 TeV is 47.8 pb, and 0.72 pb for leptonic ($l = e$, μ) channels and Z on mass shell. This process has a very distinct experimental signature with three high p_T leptons and high $\not\!\!E_T$. At least two leptons must have like-flavour of opposite sign and invariant mass consistent with the mass of Z boson. Background processes include Z+jets, $Z\gamma$, ZZ and $t\bar{t}$ production. Signal extraction can be achieved with the following cuts: (1) two same-flavour opposite sign leptons, which satisfy $|M(ll) - M_Z| < 10$ GeV, and at least one with $p_T > 25$ GeV; (2) $\not\!\!E_T > 25$ GeV; (3) vector sum of jet transverse momenta less than 200 GeV; (4) vector sum of p_T of charged leptons and $\not\!\!E_T$ less than 120 GeV; (5) third lepton (not from Z decay) is required to have $p_T > 20$ GeV, and transverse mass M_T determined by the third lepton p_T and $\not\!\!E_T$ must be within $40 < M_T < 120$ GeV. For 1 fb^{-1} of data 53 WZ and 7 background events are expected. With BDT analysis the number of expected WZ and background events is 128 and 16 respectively for 1 fb^{-1} of data. Expected limits on anomalous WWZ couplings at 95% C.L. are: $-0.095 < \Delta\kappa_Z < 0.222$, $-0.015 < \lambda_Z < 0.013$, and $-0.011 < \Delta g_Z^1 < 0.034$, for $\Lambda_{FF} = 2$ TeV, and for 10 fb^{-1} of data.

Summary. The increased energy and luminosity at the LHC will allow for substantial progress in diboson physics studies and marks a new sensitivity domain with respect to that currently available from the Tevatron data. The results show that ATLAS can measure the WW, $W\gamma$ and WZ signal with early (≈ 100 pb^{-1}) LHC data. With 10 fb^{-1} charged triple gauge boson couplings can be measured with an accuracy $\mathcal{O}(10^{-2})$ assuming $\Lambda_{FF} = 2$ TeV.

References

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